Airport Digital Transformation

Best Practices on Intelligent Aircraft Stand Allocation in Shenzhen Bao'an International Airport
Shenzhen Bao’an International Airport (SZX) validates a component of the NEXTT vision

Since 2017 and the signing of an MoU between IATA and Shenzhen Airport group, both parties have been collaborating to reconceptualize the entire airport space with the goal of providing a seamless end-to-end journey for passengers, baggage and cargo.

Digital transformation of the aircraft turnaround processes is fundamental within our vision. Shenzhen’s case study addressing stand allocation illustrates how the airport has used a variety of operational data sources combined with AI. This has improved the allocation of stands and consequentially the efficiency across the airport. This provides a compelling validation of this aspect within the NEXTT vision. Confirms the advantages of using big data and AI technologies to coordinate aircraft turnarounds.
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# 1 Executive Overview

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<th>Submitting Airport / Company</th>
<th>Shenzhen Bao’an International Airport</th>
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<tr>
<td>Name of Project / Solution</td>
<td>Shenzhen Airport Intelligent Aircraft Stand Allocation</td>
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<tr>
<td>Short Description (max. 5 sentences)</td>
<td>Shenzhen Bao’an International Airport (hereinafter called Shenzhen Airport for short) has set up an Intelligent Aircraft Stand Allocation System at the end of 2019. The purpose of this system is to implement intelligent allocation and scheduling of aircraft parking space resources by using artificial intelligence (AI) technologies, and optimize the core operating indicators of the airport, such as increasing the airbridge turnover and reducing the aircraft taxiing conflict probability, thereby improving the overall operation efficiency and passenger experience of the airport.</td>
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| Main Benefits Obtained (max. 3) | This system helps Shenzhen Airport:  
- Reduce the aircraft ground taxiing collision probability by using AI algorithms in aircraft stand allocation to increase the allocation plan precision, and visualizing the allocation result to make it easier to be quickly checked.  
- Increase the airbridge usage, so as to maximize the airport resource utilization, reduce the related operating costs, and improve the passenger travel experience.  
- Use AI-enabled allocation mechanisms to reduce the strong dependence on allocation staff’s personal allocation experience, so as to minimize the manual workload and significantly improve the airport’s aircraft allocation automation level. |
| Commercial Advantage / Business Case | After this intelligent system is deployed, compared with the original software-aided manual allocation mode, under the same operating environment and conditions, the airbridge usage has increased by nearly 5%, and the airbridge turnover has been added by about 0.6 aircraft per day. This means that at least 30 more aircrafts and 5000 more passengers can use airbridges for boarding or disembarking each day, which will reduce use of a minimum of 24,000 shuttle buses for a year. This improvement effectively increases Shenzhen Airport’s utilization of the aircraft parking space and other related airport |
### 2 Introduction

#### 2.1 Current Model of Stand Allocation and Development Trend

Aircraft parking stands are a resource center for an airport’s operation, and it is a conjunction of aircraft, passenger, luggage, and ground transportation. In an airport’s information management process, parking stand allocation not only directly affects the safety of aircraft parking, but also affects planning and allocation of related resources, such as boarding gates, shuttle buses, baggage claim system and so on. In special cases such as flight delay, cancellation, and turnback, the original parking allocation plan needs to be adjusted accordingly.

Parking stand allocation is based on various factors such as flight properties, timetable, and aircraft model. It generally falls into two phases: stand pre-allocation and real-time stand adjustment. After obtaining the departure and arrival plans of all fights for a day, the aircraft scheduling management team works out the parking plans for all flights in advance based on the known allocation factors and constraints. In special cases, real-time adjustment of the parking plans are made for those aircrafts that may go into taxiing or parking conflicts with other aircrafts due to the change of airport operation conditions.

<table>
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<tr>
<th>Current Status</th>
<th>The Intelligent Aircraft Stand Allocation System has been officially put into use by Shenzhen Airport in December 2019.</th>
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<tr>
<td>Project Duration</td>
<td>Shenzhen Airport has started feasibility research on using an AI-based intelligent aircraft stand allocation system as early from December 2017. In December 2018, it started the project of developing this system. After one year of development, testing and verification, this intelligent allocation system has been successfully deployed and put into use in December 2019.</td>
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| Affected Process Area | Passenger Handling  
Baggage Handling  
Apron / Aircraft Turnaround  
IT Support Processes  
Other, specify: _______ |

**2.1 Current Model of Stand Allocation and Development Trend**

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At present, most airports in China perform manual aircraft stand allocation on a Gantt chart system based on a set of allocation rules and constraints. In this mode, allocation staff need to memorize lots of allocation rules and constraints, and also need to cope with many unexpected conditions that may lead to a high probability of aircraft taxiing conflicts, so the allocation efficiency stays at a low level.

The emergence of intelligence technologies in recent years has research institutes and technology companies actively researching how advanced algorithms in aircraft parking stand allocation and intelligent allocation adjustment systems can be applied to reduce the aircraft taxiing conflict probability and maximize the parking stand usage, thereby improving the airport resource management and operating efficiency.

2.2 Airport Introduction

Shenzhen Airport is located in the Bao'an District of Shenzhen, 32 kilometers away from the downtown, with a total airfield of 7,700,000 square meters, terminal buildings covering 451,000 square meters, and cargo facilities of 1,660,000 square meters. It provides 199 parking stands, including 62 airbridge stands, and two runways. The second runway, with a length of 3,800 meters and a width of 60 meters, was officially put into operation in 2011 at a 4F-class standard, allowing it to accommodate any type of passenger aircrafts in the world.

Shenzhen Airport was officially opened in October 1991. As of 2019, it runs more than 180 domestic and international air routes. For the whole year of 2019, the airport has recorded a total passenger volume of more than 50 million, including over 5 million international passengers, making Shenzhen Airport one of the world's busiest large sized airports.

In February 2019, the State Council of China released the Outline Development Plan for Guangdong-Hong Kong-Macao Greater Bay Area (GBA), proposing a world-class airport cluster to be built in the GBA, indicating that airport development has been included as part of the country’s national development strategies for the GBA. Based on the unique location advantages of Shenzhen as a "Special Zone, Bay Area, and Free Trade Zone", Shenzhen Airport is ambitious to build an advanced and efficient "air, land, marine, and rail" integrated transportation system, set up a passenger and freight network serving Asia Pacific and connecting to Europe and America, and grow into a core international aviation hub in the GBA.

In September 2017, Shenzhen Airport signed a Memorandum of Understanding with the International Air Transport Association (IATA), participating in IATA/ACI NEXTT initiative as one of the earliest members with another four global airports including Dubai, London Heathrow, Bangalore, and Amsterdam Schiphol. The NEXTT project
aims to explore new travel experience technologies and drive industry cooperation. As the only member from China, Shenzhen Airport has positioned itself at the very frontline to actively participate in international cooperation and contribute its technology innovation achievements to the whole industry, in an effort to serve continuous passenger travel experience and airport management efficiency improvements.

3 Situation

3.1 Challenges

In recent years, Shenzhen Airport has been growing very fast in its passenger and cargo businesses. With its total passenger volume exceeding 50 million in 2019, its dual-runway capacity has reached the allowed maximum volume of 54 aircrafts/hour.

While the passenger traffic is increasing at a high speed, the airport ground resources cannot be quickly expanded. As a result, ensuring safe and efficient operation of the airport under limited resources has become a great challenge for the operation control of the airport.

Through study and research, Shenzhen Airport determines to address these issues brought by resource constraints by maximizing the airport resource usage. As the resource center of a whole airport, parking stand usage plays a critical role in affecting an airport's overall operational efficiency. Currently, Shenzhen Airport executes parking stand allocation based on manual decisions with the aid from a Gantt chart software. In peak business hours when parking stands, especially airbridge served stands are in tight availability, this manual allocation method has the following disadvantages:

- Low allocation work efficiency
  Shenzhen Airport currently has 199 parking stands, including 62 airbridge-served stands. In traditional mode, a large number of allocation rules must be manually considered and applied, such as flight schedules, airplane model, flight properties, route properties, and various priority rules. As a result, the allocation decision heavily relies on allocation staff's experience and is quite time-consuming.
  In general, the allocation team needs to work in shifts round the clock to dynamically allocate and adjust parking stands, and an extra workload of 3 hours is required for overnight flight allocation. In addition, with the traditional method, it is difficult to accurately evaluate the allocation efficiency for overnight and transit flights with real-time monitoring data. When facing emergencies, such as departure or arrival plan cancellations due to bad weather, delayed arrival, or forced landing, it is also hard to adjust the original allocation plans as swiftly as expected.

- Difficult to optimize core operating indicators
  To optimize parking stand allocation plans, multiple factors must be considered, such as how many airlines can use the airbridges (airline airbridge usage), how
many passengers in total can use the airbridges (passenger airbridge usage), passengers’ walking distance, aircraft taxiing conflict probability, and the optimization target. In traditional allocation mode, it is difficult to adjust the allocation strategy to optimize a specific indicator while keeping the global allocation plan at a high efficiency level, for example, to minimize the collision probability in extreme weather, or maximize the airbridge usage in good weather.

- Low intelligence
  The airport is facing challenges from rising demands for quicker flight information synchronization and smoother information sharing among its multiple IT service systems. Information about the flying area layout, taxiing program design, and the commercial area layout inside the terminal buildings cannot be integrated and exchanged with the traditional software-aided stand allocation system. Also, data from different sources involved in stand allocation, such as airlines, ground service assurance, and air control authority, cannot be efficiently and flexibly collected and converged to the traditional system to make deeper and comprehensive analysis, so as to automatically make decisions for adjusting the allocation plan.

- Low efficiency for global allocation adjustment
  In traditional allocation mode, the stand allocation result cannot be quantified in real time, making it difficult to accurately evaluate the effect of each adjustment for a single stand and for the global allocation plan. With a daily throughput of more than a thousand flights and over 140,000 passengers at Shenzhen Airport, the tradition allocation mode is becoming less capable of quickly and accurately adapting to dynamic changes of allocation rules, and therefore turning into a critical factor affecting the airport’s operating efficiency improvement.

3.2 Solution Design

Based on the business challenges and future expectations, Shenzhen Airport vested in research on the application of AI technology for stand allocation from the end of 2017, and commenced system development from the end of 2018.

This AI-aided intelligence system has all related data, including stand properties, flight information, delay, and change information integrated, analyzed, and deep mined on a underlying big data platform, and uses AI algorithms to make automatic stand allocation decisions, predict flight delays, and automatically publish the allocation plans within seconds. All the allocation results are displayed on UI interfaces, with multiple measuring dimensions provided for operating staff to view and use for manual decision making.

This AI allocation system is designed with the following functions:

- Automatic allocation: The system can automatically match all the defined stand allocation and constraint rules to work out allocation plans under different
conditions. In addition, it allows a possibility for commanders to execute manual allocation interventions, to meet the demands in exceptional cases.

- **Global optimization**: The system uses mathematical optimization and heuristic algorithms to globally optimize the core airport operating indicators.
- **Flexible configuration**: The system supports multi-dimensional policy configuration for core indicators, allocation rules, and constraint rules according to the objective of optimizing a specific operating indicator.
- **System management**: The system provides functions including user role assignment, permission configuration, and log management for comprehensive allocation process management and prevention of system exceptions.
- **Capability expansion**: In addition to the allocation optimization objectives that have been already implemented in the existing system, the system supports quick development iteration cycles to add more allocation optimization dimensions and objectives, while maintaining compatibility with the current system functionalities.

From the perspective of end use, this AI allocation system dynamically displays the allocation status and details on various view interfaces, including a panoramic floor view, a progress Gantt chart view, an indicator comparison chart view, and a view of free stands charts. Allocation staff can view all the monitored operating indicators from the UI interfaces to learn about the dynamic airport operating situations. These indicators include the overall parking stand usage, trends of stand occupation by departure and arrival flights, overall airbridge turnover, and airbridge usage by various measure dimensions, such as by airlines, passengers, ground services, aircraft models, and airline types.

### 3.3 Solution Implementation

This intelligent allocation system applies to three use scenarios:

- **Batch allocation**: After obtaining all flight plans, the system allocates the parking stands for all departure and arrival flights in a certain period in advance.
- **Real-time adjustment**: When encountering an exception, bad weather, or emergency, the system adjusts the original stand assignments for those affected flights in real time, based on the aircraft and stand operating status, as well as other allocation basis and rules.
- **Manual intervention**: As required in exceptional cases, the commanders can manually adjust the automatically-generated stand plans, and make new assignments.

### 3.4 Benefits

#### 1. Current Benefits

According to the tests of the intelligent allocation system and the comparisons with the traditional allocation mode, the AI system has shown the following advantages:
1) Enhance the airport operation security management capability. By using AI allocation algorithms and visualized allocation result graphs, the airport has transformed its stand allocation work from a manual-decision-intensive mode to an intelligent mode. Less dependence on manual operations helps to reduce the risks of taxiing collisions resulting from manual allocation mistakes, thereby greatly improving the airport’s security management level.

2) Significantly improve the passengers’ travel experience. According to the tests, this AI allocation system helps increase the airbridge turnover by nearly 0.6 aircraft, which means at least 30 more flights can use airbridges each day, benefiting 5,000 more passengers a day, or over 2 million passengers in a whole year, reducing use of at least 24,000 shuttle buses a year. Using airbridges for boarding and disembarking can greatly shorten passengers’ walking distance, boarding and disembarking durations, and avoid burdensome walking process, thus effectively improving the passengers’ travel experience in the airport.

3) Improve the airport’s overall operation efficiency and reduce the operating cost. The use of AI algorithms has maximized the usage of aircraft parking stands, especially airbridge served stands, accordingly reducing the use of ground transportation vehicles, and shortening the average ground service duration. These improvements have contributed to good flight scheduling assurance, and reduced the work intensity of ground service personnel, as well as the cost on human resources, facilities, and transportation.

4) Energy-saving and environment friendly. Thanks to the rise of the airbridge usage, more aircrafts can use electric-powered bridge-served facilities for boarding and disembarking, and less transportation vehicles are required, meeting the airport’s development requirements on energy conservation and environment friendliness.

2. Future Benefits

The deployment of the intelligent stand allocation system confirms Shenzhen Airport’s position as a pioneer in exploring innovations in civil aviation digitalization technologies, and also demonstrates their deep understanding of long-term vision on the path of development through continuous technology innovations. In an effort to lead the civil aviation technology advancement, and serve its strategic development target of building a world-class airport cluster in the GBA, Shenzhen Airport will continue to pursue its exploration of AI technology for innovation in the following areas:

1) Through wider use of AI technologies and AI capability accumulation, the airport can better develop the extended capabilities of the Advanced Surface Movement Guidance & Control System (A-SMGS), which allows for safer, quicker aircraft taxiing at a higher level of efficiency.
In addition, further use of AI technologies based on the current intelligent stand allocation system will enable Shenzhen Airport to develop smarter applications to deeper analyze and use the data generated by other stand-centered airport resources, such as boarding gates, baggage turntables, and terminal building commerce, therefore largely maximizing the airport’s overall resource utilization.

2) Establish a comprehensive simulation system, which will be used in planning, construction, operating rule setup and adjustment of various airport resources, as well as the establishment of a better training system in the airport’s future information system building and evolution.

3) While continuously expanding the AI technology application domain, the airport will put a focus on the research and exploration of the challenges and issues posed by the new model of human-AI interactions, such as the mutual trust relationship between human and AI, and the negative impacts of using AI applications, in a positive and active contribution to the safe and quick application of new technologies throughout the industry.

4 Solution Introduction

(1) Functions

From an end user’s perspective, the intelligent stand allocation system is a business application system. It displays the overall stand allocation status through multiple UI views, including a panoramic view, progress Gantt chart view, indicator comparison chart view, and remaining stand chart view. It also displays all monitored indicators by various categories.

This allocation system has an underlying big data platform, which collects data from all connected management systems, including the Flight Information Management System (FIMS), Operating Resource Management System (ORMS), Airport Collaborative Decision Making (A-CDM) system, Automatic Dependent Surveillance - Broadcast (ADS-B) system, as well as meteorological and runway data in real time or offline. With the aggregated data, the system builds various themed libraries, performs comprehensive analysis of related objects such as flights, stands, and runways, and identifies matches based on more than 60 configurable business allocation rules defined by the airport.

- Basic rules: includes flight plans, aircraft model and size, stand location and size, flight properties (domestic, international, or combined), and stand collision probability;
- Priority rule: stand priority can be assigned using many dimensions: on a commercial basis by airline, with large-sized aircrafts, transit flights, short-time pass-by flights, flights carrying VIP passengers, and aircrafts in an emergency condition or undertaking a special task.
• Temporary factors: including bad weather, airport construction, temporary flights, flight delays, and passenger emergencies.

Based on the preceding rules and factors, the intelligent allocation system creates an AI algorithm engine based on mathematical optimization and heuristic algorithms, and performs automatic batch stand allocation in most scenarios.

When an adjustment is triggered, the system automatically reallocates stands to flights according to the configured optimization objective, such as increasing the airbridge usage. In special cases, the commanders can also manually adjust the automatically-generated allocation plans by locking or unlocking a stand on the floor view UI, according to the flight, area, airline, and stand conditions, after which the system will return to automatic work mode to reallocate stands to flights according to the revised configurations.

From the perspective of functionalities, the system provides the following UI views for commanders to learn about the operating status in real time.

Figure 1: Stand allocation dashboard

![Stand allocation dashboard](image)

Figure 2: Floor plan

![Floor plan](image)
Figure 3: Stand allocation Gantt chart
(2) System software architecture

As shown in the following figure, the intelligent stand allocation system builds an AI platform on the airport's unified big data platform to implement functions such as machine learning, enhanced learning, linear programming, evolutionary learning, search, and recommendation. The powerful AI platform is able to host multiple algorithm engines built to execute intelligent stand allocation logic and adjustment, some of which include the prediction engine, intelligent rule engine, intelligent scheduling optimization engine, and recommendation engine. The presentation layer's user friendly features consist of a unified interactive platform with award-winning UI to enable visualized management of stand resource management.
• Big data platform module: It is used for data acquisition and maintenance and provides data for upper-layer services, including ORMS, ADS-B, A-CDM, and operation and control systems.

• AI platform module: Provides underlying algorithms for upper-layer engines, including various algorithm libraries such as machine learning, enhanced learning, linear programming, evolutionary learning, search, and recommendation.

• Engine system module: Provides decision-making basis for various services, including the prediction engine, intelligent rule engine, intelligent scheduling optimization engine, and recommendation and evaluation engine.

• Display interaction platform module: Provides users with visualized and scenario-based interaction capabilities, such as accessing status views, system settings, query statistics, and solution management interfaces.

• System operation and maintenance module: Provides system permission configuration and management functions, allowing administrators to perform system management, such as user management, role management, authentication and authorization, operation audit, system monitoring, alarm management, and system configuration.

(3) How the algorithm engines work
As the core capability module of the intelligent allocation system, the AI algorithm engines work in the following process:

1. The AI platform obtains data from the big data platform, including stand data, stand configuration data, and flight data, and then extracts all the required information, such as the stand information, aircraft information, flight information, aircraft model information, VIP passenger information, stand conflict information, ground service information, taxiing information, meteorological information, and the planned stand assignment information.

2. The AI platform integrates the obtained information into the intelligent analysis and prediction engine, intelligent rule engine, simulation and evaluation engine, and intelligent scheduling optimization engine.

3. The intelligent analysis and prediction engine uses real-time flight information, environment information, and history flight information to make flight delay and remaining stand predictions by analyzing allocation rules based on machine learning and deep learning.

4. The intelligent rule engine performs scheduling and planning learning and provides allocation plans for the intelligent scheduling optimization engine, based on the history flight allocation information, and the analysis information from the intelligent analysis and prediction engine and simulation.
5. The intelligent scheduling optimization engine integrates the real-time flight and environment information, prediction information from the intelligent analysis and prediction engine, and recommended assignment plans from the intelligent rule engine, and uses static scheduling algorithms to allocate stands for flights in advance, or uses dynamic scheduling algorithms to perform dynamic stand reallocation.